International Journal of Agricultural Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 7, Issue 2, Apr 2017, 209-216

MAGNITUDE OF HETEROSIS FOR YIELD AND ITS COMPONENTS IN HYBRID RICE (*ORYZA SATIVA* L.)

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ABSTRACT

Performance of sixty F_1 hybrids along with their 23 parents and three standard varieties was evaluated in a randomized complete block design with three replications during Sali, 2013. Significant variation was observed for parents, hybrids and hybrids versus parents for most of the yield and yield related characters. Grain yield exhibited mid parent heterosis varying from -88.7 (IR 79156A/IET 19916) to 151.5% (IR 58025A/Prafulla), heterobeltiosis from -91.9 (IR 79156A/IET 19916) to 128.2% (IR 58025A/Prafulla) and standard heterosis ranging from -91.3 to 56.5% over the late maturing check Ranjit, -86.2 to 148.3% over medium duration check TTB 404 and -91.9 to 44.4% over the hybrid check JKRH 401. Non-significant or negative heterosis for grain yield in most hybrids was attributed to spikelet sterility of varying magnitudes. Significant and desirable SCA effects for component characters resulted in significant SCA effect and heterosis for grain yield.

KEYWORDS: F_1 Hybrids, Heterosis, Mid-Parent Heterosis, Heterobeltiosis & Standard Heterosis

Received: Jan 20, 2017; **Accepted:** Feb 24, 2017; **Published:** Mar 07, 2017; **Paper Id.:** IJASRAPR201729

Original Article

INTRODUCTION

Rice is a staple food for more than half of the world population (Vanniarajan *et al.*, 2012). Globally, rice is the most important food grain from a nutritional, food security or economic perspective (Smith and Dilday, 2003). The current levels of rice production do not meet the future demand. The world population has been projected at 8.27 billion by 2030, demanding an increased rice production of 771 million tonnes (Badawi, 2004). According to 2016 world population data sheet (Anonymous, 2016), India's population would increase from 1.329 billion in 2016 to 1.708 billion in 2050, surpassing the China's population. Thus, it is a challenging task to ensure food and nutritional security of India's ever increasing population. India, being the second largest producer of rice in the world next to China, has an area of 44.0 million hectares and production of 104.8 million tonnes of rice (Anonymous, 2015).

Rice yields increased by about 30% due to the development of semi dwarf varieties (Fang *et al*., 2004), and an additional 15-20% was achieved through the use of heterosis (Yuan, 2003). Hybrid rice is a proven and economically viable option to boost rice production. Rice hybrids were first commercialized in China during late 1970s. In India, first rice hybrids (APHR 1, APHR 2) were released in 1994. Gradually hybrid rice technology has gained importance in India with a total cultivated area of about 2.5 million hectares (Singh *et al*., 2016) and till 2013 as many as 65 hybrid rice varieties have been released under public and private sectors (Singh *et al*., 2015).

Development of heterotic rice hybrids needs careful selection of parental lines to enable exploitation of maximum heterosis. The parental lines of a hybrid combination should complement each other for important agronomic characteristics to realize usable heterosis. High heterosis results from significant specific combining ability (SCA) effects attributable to the presence of non-additive genetic variance due to dominance and/or epistasis. Therefore, combining ability analysis and estimation of heterosis for yield and its component characters are important pre-requisites in hybrid rice breeding. High SCA effects and heterosis for grain yield and related traits in rice have been observed in earlier studies (Faiz *et al*., 2006; Saleem *et al*., 2008; Bagheri and Jelodar, 2010; Tiwari *et al*., 2011; Thakare *et al*., 2012; Latha *et al*., 2013). Faiz *et al*. (2006) obtained the highest positive heterobeltiosis for grain yield (41.83%), number of productive (11.04 %) and number of filled grains (7.39 %) in the cross IR69616A/Basmati 385. Tiwari *et al*. (2011) observed heterosis for grain yield ranging from 11.63 to 113.04% in 43 hybrids over the better parent and from 10.48 to 71.56% in 46 hybrids over the standard variety. Most of these crosses also exhibited significant heterosis for number of fertile spikelets and number of spikelets per panicle. Identification of potential cross combinations with heterotic effects for yield and its component traits also facilitates the conventional breeding programmes to create wide range of variability in segregating generations. Manifestation of high heterosis for grain yield is of primary importance for commercial exploitation of hybrids. The present study is therefore aimed at estimating the heterotic effects as an aid in selecting desirable parents and crosses for the exploitation of heterosis.

MATERIALS AND METHODS

The present investigation was conducted at the Instructional Cum Research farm of Assam Agricultural University, Jorhat (India) during *Sali*, 2013. Three cytoplasmic male sterile (CMS) lines - IR 58025A, IR 68888A and IR 79156A carrying wild abortive (WA) cytoplasm and 20 restorers - *Longai*, *Jalkunwari*, *Badal*, *Bahadur*, *Ranjit*, IET 18648, IET 19916, IET 20800, IET 21480, Kmj 13S 3-1-3, IET 20771, Swarna Sub 1, *Jalashree*, IET 21850, IET 19189, *Kolong*, IR69715-123-1-3R, *Ketekijoha*, *Improved Samba Mahsuri* and *Prafulla* were used to generate 60 F_1 hybrids following line x tester design during *Sali*, 2012. Two popular pure line varieties *Ranjit* of late duration, TTB 404 of medium duration and a hybrid JKRH 401 were used as checks. All the 60 F_1 hybrids, 23 parents along with the checks were raised in randomized block design with three replications during *Sali*, 2013. Each genotype was grown in single rows of 2.4 m long with 20 x 20cm spacing. Each hill was planted with single seedling. A border row was planted on both sides of each replication with the pure line check *Ranjit*. Recommended package of practices for Assam was followed to raise a good crop. Data were recorded on five random hills from the central portion of each row for the 86 genotypes. The observations were recorded for sixteen characters *viz.*, relative leaf water content (%), SPAD value, days to first flowering, days to 50% flowering, days to maturity, plant height (cm), culm length (cm), panicle length (cm), number of productive tillers per plant, number of grains per panicle, number of chaffs per panicle, spikelet fertility (%), 1000-grain weights (g), biological yield (g), grain yield (g) and harvest index (%). The magnitude of heterosis in relation to mid parent, better parent and standard variety was worked out. These were calculated as percentage increase or decrease of F_1s over the mid parent (MP), better parent (BP) and standard variety (SP) values as given by Virmani *et al*. (1997).

RESULTS AND DISCUSSIONS

Commercial exploitation of hybrid vigour is feasible only if the vigour is in excess of prevailing commercial check and better parent. Superiority of hybrid over mid parent is of no importance since it does not offer any advantage over the better parent. The range of mid parent (relative heterosis), better parent heterosis (heterobeltiosis) and standard

heterosis over *Ranjit*, TTB 404 and JKRH401 for the 16 characters are presented in Table 1. The degree of heterosis varied from cross to cross and from character to character. Alam *et al*. (2004) in upland rice observed varying degree of heterosis for yield and its related traits.

Relative Leaf Water Content, % (RLWC)

The range of mid-parent heterosis with respect to relative leaf water content was from -22.15 (IR 58025A/Kmj 13S 3-1-3) to 12.01% (IR 79156A/IET 20800). The cross combination IR 79156A/IET 20800 exhibited significant positive heterosis for this character. Standard heterosis over the hybrid check JKRH401 varied from -10.4 (IR 58025A/IET 21850) to 28.9% (IR 58025A/*Improved Samba Mahsuri*) having 48 numbers of significant positive heterotic hybrids for RLWC.

SPAD Value

Significant positive mid-parent heterosis was observed in 20 cross combinations for SPAD value whereas heterobeltiosis was noted in 7 cross combinations. Standard heterosis over the hybrid check was recorded in two crosses - IR 58025A/*Improved Samba Mahsuri* and IR 68888A/IET 20771.

Days to Flowering and Maturity

Significant negative heterosis is desirable for days to flowering and maturity. Early maturing hybrids can produce more yields per day and fit well in multiple cropping systems. Most of the test hybrids registered significant negative mid-parent heterosis, heterobeltiosis as well as standard heterosis. Standard heterosis over the late maturing pure line *Ranjit* was observed in 55 cross combinations. Early maturity in hybrids had been reported by Lokaprakash *et al.* (1992) and Patil *et al.* (2003).

Plant Height and Culm Length

Dwarf of semi dwarf plant type is an important character of hybrids to withstand lodging. Cross combinations exhibited desirable heterosis for plant height were IR 79156A/IET 20771 (-25.4%), IR 79156A/IET 21850 (-30.5%), IR 79156A/IET 18648 (-21.1%) and IR 79156A/*Improved Samba Mahsuri* (-20.3%) over both better parent and standard check *Ranjit*, respectively. Sarker *et al.* (2002) also reported negative heterosis for plant height.

Panicle Length

A hybrid with long panicle is desirable as the spikelets attached to its primary and secondary branches would increase proportionally with increase in panicle length. Two hybrids namely IR 58025A/IET 21850 and IR 79156A/*Ketekijoha* exhibited significant mid-parent heterosis, heterobeltiosis as well as standard heterosis over all the three checks (*Ranjit*, TTB 404 and JKRH 401). These findings are in accordance with the findings of Panwar *et al.* (2002) and Shanthala *et al.* (2006).

Effective Tillers per Plant

A wide range of relative heterosis, heterobeltiosis and standard heterosis was registered over *Ranjit*, TTB 404 and JKRH 401. Significant positive heterosis, heterobeltiosis and standard heterosis was observed in 16 cross combinations.

Grains/Chaffs per Panicle and Spikelet Fertility

The cross combination IR 58025A/IET 18648 exhibited significant positive relative heterosis (97.57%), heterobeltiosis (49.73%) and standard heterosis over the check TTB 404 (141.1%) and JKRH 401 (58.72%) for grains per

panicle. The extent of spikelet fertility is an important character which directly influences the ultimate grain yield. Positive heterosis for spikelet fertility and negative heterosis for chaffs per panicle were non-significant. However, the standard heterosis over JKRH 401 varied from -98.03% (IR 79156A/*Improved Samba Mahsuri*) to 14.09% (IR 79156A/*Kolong*). Superiority of this character in hybrids was also reported by Panwar *et al*. (2002).

Thousand Grain Weights

Thousand grain weights is an indicator of grain yield. For this trait, standard heterosis over the check *Ranjit* ranged from -7.69% (IR 79156A/IET 21480) to 42.3.1% (IR 58025A/*Jalashree*). Forty four cross combinations showed significant positive standard heterosis in the range of 15.38% to 42.3%. Similar results were reported by Verma *et al*. (2004) and Shanthala *et al*. (2006).

Biological Yield

The range of standard heterosis over the check *Ranjit* varied from -59.6% (IR 79156A/Kmj 13S 3-1-3) to 101.43% (IR 58025A/Swarna Sub 1). The only cross combination with significant positive standard heterosis over the check *Ranjit* was IR 58025A/Swarna Sub 1which also exhibited significant positive mid-parent heterosis, heterobeltiosis and standard heterosis over the other two checks.

Grain Yield

The range of heterosis was -88.7 to 151.07 over mid-parent, -91.94 to 128.23 over better parent and -91.27 to 56.46, -86.15 to 148.31 and -91.94 to 44.44 per cent over the standard checks *Ranjit*, TTB 404 and JKRH 401, respectively. High heterosis over *Ranjit* was manifested in the crosses IR 58025A/*Prafulla* (56.46%), IR 79156A/*Bahadur* (53.45%), IR 58025A/Bahadur (53.45%) and IR 58025A/IET 20771A (49.12%). Relative heterosis and heterobeltiosis in both positive and negative directions was reported by Chaudhary *et al*. (2007) and Neelam *et al.* (2013).

To obtain higher grain yield per plant, heterosis over better parent and standard check should be emphasized. Based on standard heterosis over the check *Ranjit*, 14 hybrids were identified showing more than 10% yield advantage. Rest of the hybrids recorded low (less than 10%) or negative heterosis over *Ranjit*. Prakash and Mahadevappa (1989) attributed low grain yield of hybrids to spikelet sterility. Most of the hybrids in the present study showing non-significant or negative heterosis for grain yield per plant registered spikelet sterility of varying magnitudes. A comparative study of top 14 crosses with higher magnitude of mean, *SCA*, and *GCA* effects of parents, standard heterosis for grain yield over check *Ranjit* along with desirable heterosis for other characters is presented in Table 2. Mean grain yield ranged from 20.74 (IR 58025A/IET 19189) to 29.47 g (IR 58025A/*Prafulla*). Heterobeltiosis varied from 9.16 in IR 58025A/IET 19189 to 124.9% in IR 79156/*Bahadur*, while standard heterosis over the checks *Ranjit*, TTB 404 and JKRH 401 ranged from 10.12 (IR 58025A/IET 19189) to 56.46% (IR 58025A/*Prafulla*), 74.78 (IR 58025A/IET 19189) to 148.31% (IR 58025A/*Prafulla*) and 1.67 (IR 58025A/IET 19189) to 44.44% (IR 58025A/*Prafulla*), respectively. Majority of the crosses had high SCA effects for grain yield per plant as well as for other traits like panicle length, grains per panicle, productive tillers per plant and thousand grain weights. The results suggested that at least significant and desirable SCA effects of two to three component characters resulted in significant SCA effect for grain yield. Similar results have been reported by Patil *et al*. (2003) and Parihar *et al*. (2008).

CONCLUSIONS

Higher magnitude of heterosis in predominant number of crosses over standard check was observed for productive tillers per plant, number of filled grains per panicle, panicle length, thousand grain weights and grain yield per plant. Association of these characters at both phenotypic and genotypic levels was positive and significant (Eradasappa *et al*., 2007). The heterotic crosses for yield and its components could be advanced for isolating high yielding pure lines and for transgressive segregation, which appears to be ubiquitous in plant hybrids (Rieseberg *et al*., 1999).

ACKNOWLEDGEMENTS

This work has been part of the Ph D research carried out by the first author. The authors offer their sincere thanks and gratitude to the then Project Director, DRR (ICAR), Hyderabad for providing the CMS lines. All help provided by the AAU authority in terms of finance and other facilities for carrying out the investigation is greatly acknowledged.

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APPENDICES

Table 1: Range of Mid-Parent Heterosis, Heterobeltiosis and Standard Heterosis for Different Characters

Character	Mid-Parent Heterosis	Heterobeltiosis	Standard Heterosis Over the Checks		
			Ranjit	TTB 404	JKRH 401
Relative leaf water content	-22.15 - 12.01	-23.85 - 9.60	-22.10 - 12.12	-27.55 - 4.28	-10.44 - 28.90
SPAD value	-12.87 - 26.65	-20.95 - 25.09	-23.13 - 7.51	-22.67 - 8.16	-19.77 - 12.22
Days to first flowering	-46.60 - 6.19	-48.83 - -12.25	-42.63 - -5.26	-36.99 - 4.05	-24.57 - 24.57
Days to 50% flowering	- 44.61 - 7.31	-47.39 - -10.77	-41.41 - -3.79	-35.56 - 5.83	-24.92 - 23.30
Days to maturity	-30.61 - 5.52	-36.90 - -7.09	-33.94 - -2.75	-26.92 - 5.98	-15.76 - 22.17
Plant height (cm)	-34.31 - 32.94	-40.44 - 11.69	-30.50 - 15.79	-23.88 - 26.81	-27.22 - 21.25
Culm length (cm)	-46.43 - 39.98	-53.50 - 27.31	-35.50 - 31.08	-36.33 - 28.70	-29.57 - 42.36
Panicle length (cm)	-3.31 - 34.27	-9.43 - 32.72	-9.08 - 19.62	-14.55 - 12.41	-14.35 - 12.68
Effective tillers	-8.67 - 298.64	-20.49 - 240.85	-3.00 - 290.00	-20.05 - 221.43	23.83 - 397.87
Grains per panicle	-97.28 - 110.81	-97.66 - 102.85	-98.50 - 21.75	-97.02 - 141.13	-98.04 - 58.72
Chaffs per panicle	-2.42 - 407.79	-6.70 - 330.94	-45.87 - 177.78	14.20 - 486.03	-36.23 - 227.21
Spikelet fertility (%)	-97.77 - 7.43	-98.07 - 1.35	-98.08 - 10.79	-98.12 - 8.44	-98.03 - 14.09
1000- grain weights (g)	-30.86 - 41.67	-40.00 - 33.33	-7.69 - 42.31	-17.24 - 27.59	-25.00 - 15.63
Biological yield (g)	-61.50 - 217.36	-72.66 - 176.97	-59.61 - 101.43	-32.19 - 238.21	-52.62 - 136.33
Grain yield (g)	-88.70 - 151.07	-91.94 - 128.23	-91.27 - 56.46	-86.15 - 148.31	-91.94 - 44.44
Harvest index	-80.79 - 50.21	-82.21 - 39.20	-83.39 - 28.00	-84.78 - 17.22	-50.86 - 278.54

Table 2: Promising Hybrids with High *per se* Performance, Combining Ability Effect and Standard Heterosis for Yield and Its Component Traits

Cross Combination	Mean	Yield Heterosis Over the Checks			SCA Effect	GCA Line	GCA Tester	Desirable Heterosis for Other Traits
		Ranjit	TTB 404	JKRH 401				
IR 58025A /IET 19189	20.74	10.12	74.78	1.67	-0.33	1.30	3.44	DFF, DF, DM, TGW, HI
IR 58025A /IET 20800	22.67	20.35	91.01	11.11	2.41	1.301	2.63	DFF, DF, DM, PL, ET, GP, TGW, HI
IR 58025A /IET 20771	28.08	49.12	136.66*	37.66	9.37	1.30	1.09	DFF, DF, DM, PL, ET, GP, TGW, BY, HI
IR 58025A /Bahadur	28.90	53.45	143.54*	41.67	1.11	1.301	10.17**	DFF, DF, DM, CL, PL, ET, TGW, BY
IR 58025A /Jalkunwari	23.02	22.21	93.96	12.83	0.75	1.30	4.64	DFF, DF, DM, CL, ET, GP, CP, SF, TGW, BY, HI
IR 58025A /IET 18648	23.60	25.33	98.90	15.7	4.74	1.30	1.24	DFF, DF, DM, ET, GP, TGW, BY
IR 58025A /Prafulla	29.47	56.46	148.31*	44.44	9.32	1.30	2.52	DFF, DF, DM, PL, ET, CP, TGW, BY, HI
IR 58025A /Improved Samba Mahsuri	21.73	15.40	83.15	6.54	6.10	1.30	-2.00	DFF, DF, DM, ET, TGW, BY
IR 68888A /Jalashree	22.43	19.12	89.04	9.97	8.78	0.16	-2.83	DFF, DF, DM, ET, GP, BY
IR 68888A /Bahadur	21.67	15.04	82.58	6.21	-4.98	0.16	10.17**	DFF, DF, DM, CL, PL, ET, TGW, HI

Table 2: Contd.,

IR 68888A /Ketekijoha	23.20	23.19	95.51	13.73	7.72	0.16	-1.00	DFF, DF, DM, ET, TGW
IR 79156A /Kmj 13S 3-1-3	22.93	21.77	93.26	12.42	8.18	-1.46	-0.11	DFF, DF, DM, PL, ET, TGW, BY
IR 79156A /Bahadur	28.90	53.45	143.54*	41.67	3.87	-1.46	10.17**	DFF, DF, DM, CL, ET, TGW, BY
IR 79156A /Jalkunwari	25.73	36.64	116.85	26.14	6.24	-1.46	4.64	DFF, DF, DM, PL, ET, TGW, BY

DF, Days to first flowering; DFF, Days to 50% flowering; DM, Days to maturity; CL, Culm length; ET, Effective tillers; GP, Grains per panicle; CP, Chaffs per panicle; SF, Spikelet fertility; TGW, Thousand grain weights; BY, Biological yield; HI, Harvest index; PL, Panicle length and PH, Plant height.